

Arctic Oscillation and Polar Vortex Analysis and Forecasts

January 6, 2020

Special blog on winter 2018/2019 retrospective can be found here
- <http://www.aer.com/winter2019>

Special blog on winter 2017/2018 retrospective can be found here
- <http://www.aer.com/winter2018>

Special blog on winter 2016/2017 retrospective can be found here
- <http://www.aer.com/winter2017>

Special blog on winter 2015/2016 retrospective can be found here
- <http://www.aer.com/winter2016>

Dr. Judah Cohen from Atmospheric and Environmental Research (AER) recently embarked on an experimental process of regular research, review, and analysis of the Arctic Oscillation (AO) and Polar Vortex (PV). This analysis is intended to provide researchers and practitioners real-time insights on one of North America's and Europe's leading drivers for extreme and persistent temperature patterns.

During the winter schedule the blog is updated once every week. Snow accumulation forecasts replace precipitation forecasts. Also, there is renewed emphasis on ice and snow boundary conditions and their influence on hemispheric weather.

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The AO/PV blog is partially supported by NSF grant AGS: 1657748.

Summary

- The Arctic Oscillation (AO) is currently positive and is predicted to remain positive the next two weeks.
- The current positive AO is reflective of negative pressure/geopotential height anomalies in the Arctic with mixed pressure/geopotential height anomalies across the mid-latitudes. The North Atlantic Oscillation (NAO) is also positive with negative pressure/geopotential height anomalies spread across Greenland and Iceland; and the NAO is predicted to remain positive over the next two weeks as heights remain negative across Greenland.

- The general pattern across Europe the next two weeks is widespread ridging/positive geopotential height anomalies. The above normal geopotential heights and the lack of snow cover will result in widespread normal to above normal temperatures across Europe including the United Kingdom (UK). One exception is this week in Southeastern Europe as northerly flow on the backside of a trough/low pressure propagating through the Eastern Mediterranean will result in normal to below normal temperatures in the region.
- With a positive AO, the general predicted pattern for Asia the next two weeks is ridging/positive geopotential height anomalies with normal to above normal temperatures. Exceptions will be troughing/negative pressure/geopotential height anomalies and normal to below normal temperatures across the northern Indian subcontinent and Eastern Siberia the entire period. During week two increasing troughing across Siberia will bring a reduction in temperatures closer to seasonable levels.
- The predicted pattern across North America the next two weeks is strong ridging/positive geopotential height anomalies anchored south of the Aleutians forcing downstream troughing/negative pressure/geopotential height anomalies in western North America with more ridging/positive geopotential height anomalies in the Eastern United States (US). This pattern favors normal to below normal temperatures in Alaska, the Western US and widespread in Canada with normal to above normal temperatures in the Eastern US.
- In the Impacts section I discuss whether the polar vortex will ever become disrupted this winter.

Impacts

I certainly entered this winter confident that the stratospheric polar vortex (PV) would be perturbed and have been surprised so far this winter by the resiliency of the PV to disruption and that it has stayed relatively strong and quiet until now with not much more than hints of future disruptions or perturbations from the weather model forecasts. I also expected that low Arctic sea ice and a relatively warm Arctic would favor high latitude blocking/high pressure. Certainly, since late December the strong PV has coupled to the surface contributing to expansive low pressure in the Arctic and relatively cold temperatures in contrast to my own expectations. And typically, when the Arctic is cold the mid-latitudes are mild.

Heading into the winter I was not terribly bullish on a major mid-winter warming (MMW: reversal of the zonal mean zonal wind from westerly or positive to easterly or negative at 60°N and 10 hPa). We had two very impressive PV splits over the past two winters. That has only happened once before in 2008/09 and 2009/10 and there were no MMWs the next two winters. So, if an MMW happened this winter it would be exceptional based on historical records.

Though I see little support for a significant disruption of the PV in the near future, with the possible exception of possible Scandinavian blocking the latter half of January, if the PV stays strong right through the end of winter that would be highly unusual in itself, especially in the era of accelerated Arctic warming. If you watched the webinar that I gave to the Bismarck NWS, I chose two paradigm winters one where the PV was exceptionally weak and one where it was exceptionally strong. The strong PV winter was 1988/89 and what I neglect to mention in the presentation is that even in that winter in late February there was an MMW (see the polar cap height plot from that winter in **Figure i**). It was too late to impact the winter means but even the strongest PVs tend to eventually break down even prior to the final warming.

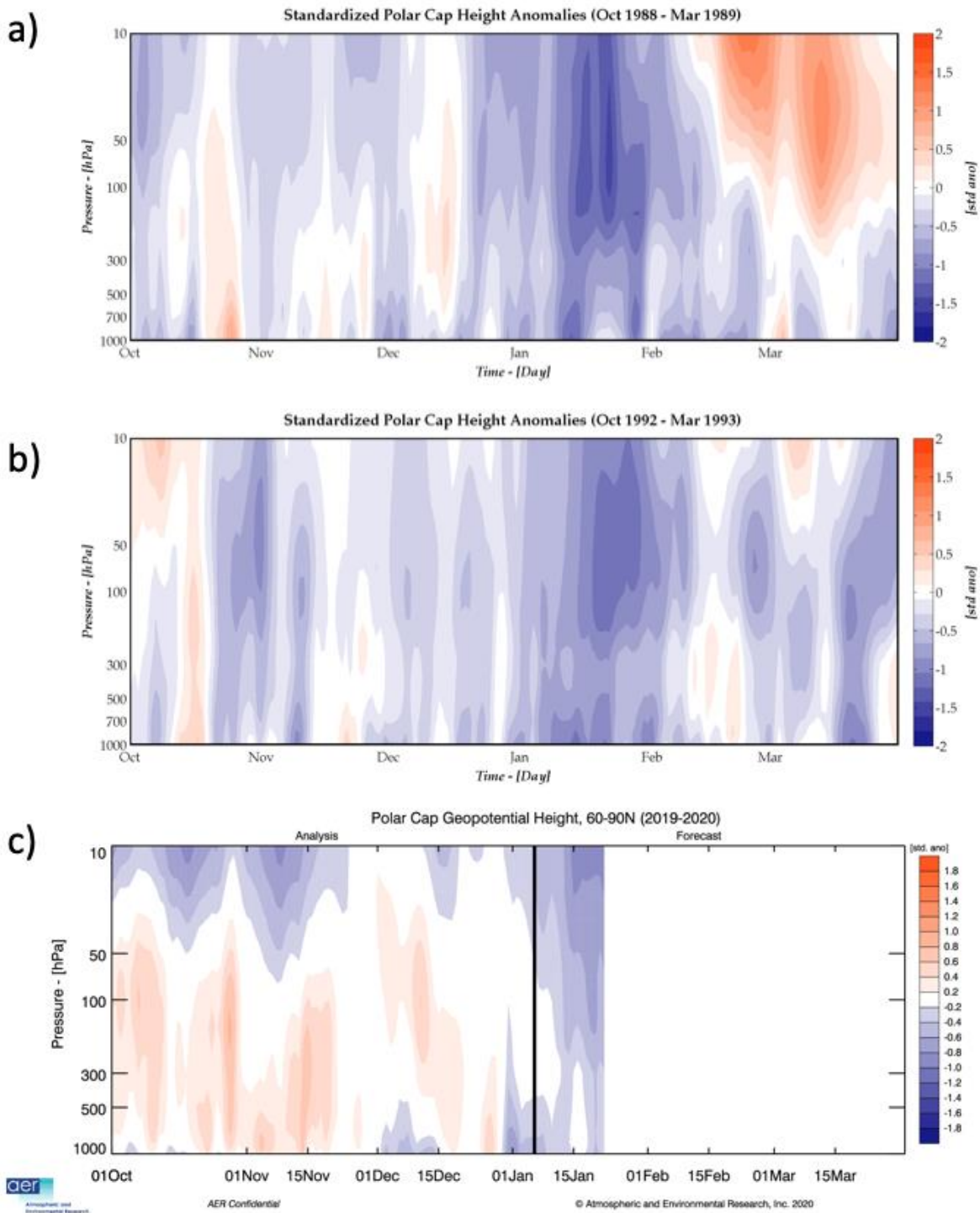


Figure i. a) Observed predicted daily polar cap height standardized anomalies from October 1, 1988-March 31, 1989 b) Observed predicted daily polar cap height standardized anomalies from October 1, 1992-March 31, 1993 c) Observed from October 1, 2019 and predicted daily polar cap height (i.e., area-averaged geopotential

heights poleward of 60°N) standardized anomalies. The forecasts are from the 00Z 6 January 2020 GFS ensemble.

There are only a few winters where the PV remained strong virtually throughout the winter most recently in 1992/93 (see **Figure i**) and 1999/00). I also included this winter in **Figure i** and so far, I don't see a reason to expect the PV to remain strong throughout the winter but there is precedent, and it is certainly plausible.

I discussed last week that it seems to me the stratosphere is becoming more conducive or favorable for at least reflective events. In **Figure ii**, I include the zonal mean zonal winds from the ECMWF analysis from late December. You can see that in the high latitudes the zonal-mean zonal winds increase from the surface right through the stratosphere. Also included is the forecast from yesterday's ECMWF forecast for January 13, 2020. The winds are predicted to increase from the surface until 10 hPa but then decreases above this. This seems to me a textbook reflective surface in the stratosphere ([Perlwitz and Harnik 2004](#)). So, if vertical atmospheric energy picks up then it would reflect off the stratosphere back into the troposphere elongate the stratospheric PV and drive a lobe of the tropospheric PV south across North America. Reflective events favor cold in Siberia but especially central and eastern North America.

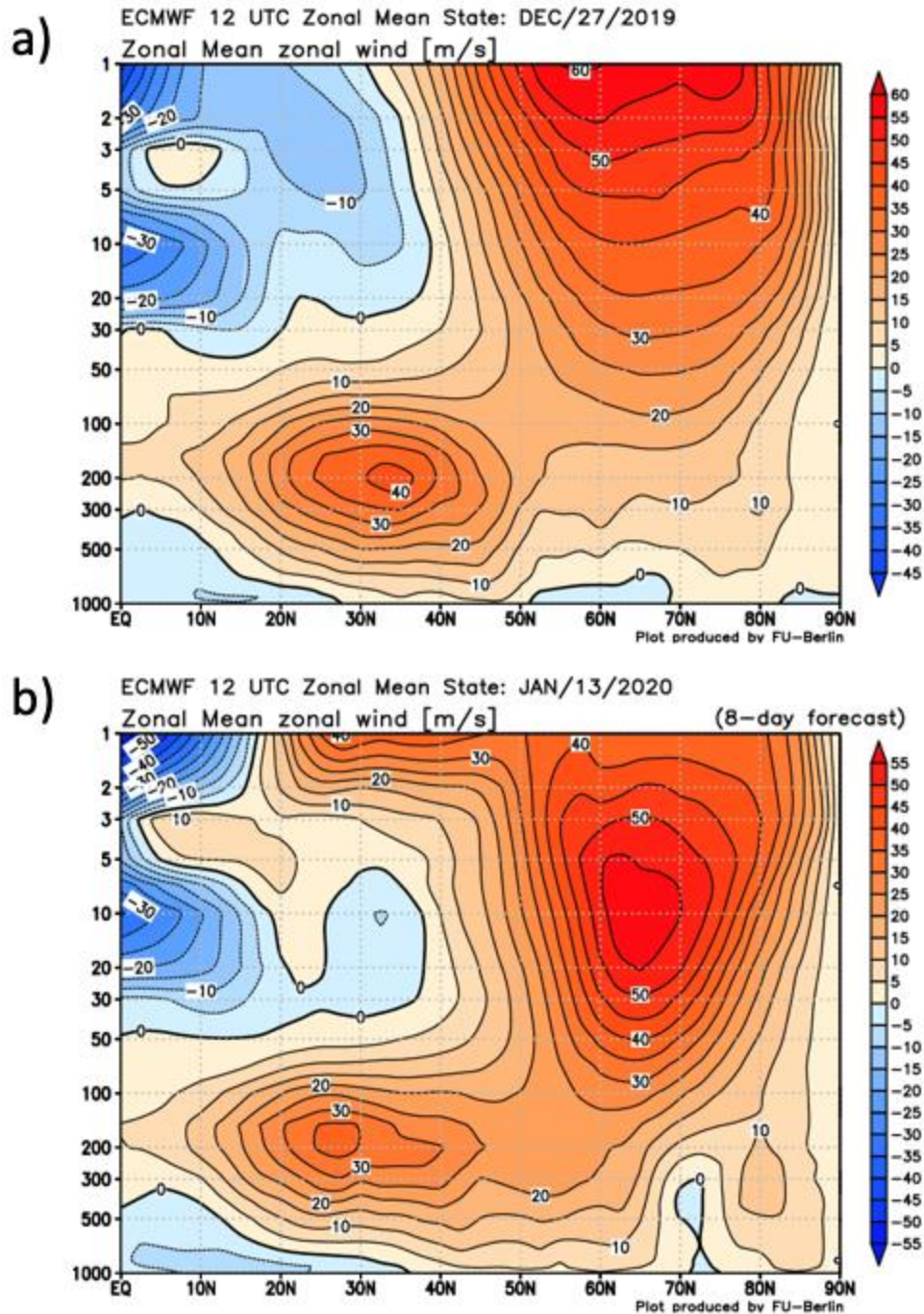


Figure ii. ECMWF analyzed zonal mean zonal winds from the equator to the North Pole and from 100 to 1 hPa (plot taken from <https://www.geo.fu-berlin.de/en/met/ag/strat/produkte/winterdiagnostics/index.html>).

This morning's GFS run seems to already suggest a similar scenario and appears to me indicative of cold air in North America (see **Figure iii**). Admittedly in my opinion the

models have struggled in their PV forecasts, so I don't want to rely too heavily on this one forecast but to predict some very cold air somewhere in North America doesn't take too much imagination at this point based on the weather model forecasts.

Initialized 12Z 10 hPa HGT/HGTa 06-Jan-2020

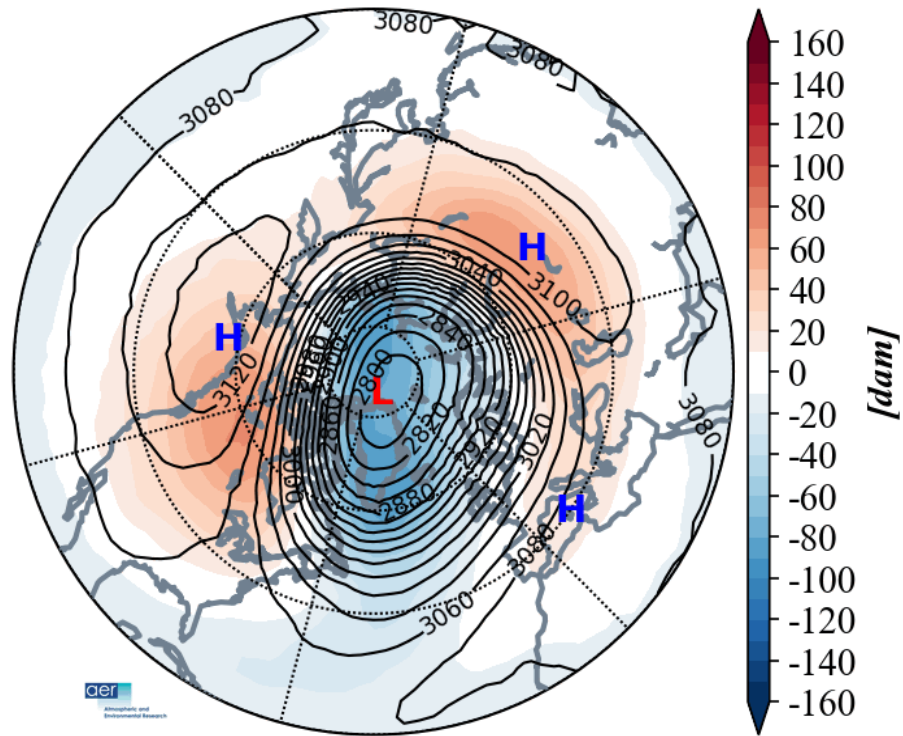


Figure iii. Polar vortex animation. Analyzed and predicted 10 mb geopotential heights (dam; contours) and temperature anomalies ($^{\circ}\text{C}$; shading) across the Northern Hemisphere from 6 – 22 January 2020. The forecasts are from the 12Z 6 January 2020 GFS operational model.

In the October 28, 2019 blog, I listed some expectations for the upcoming winter and admittedly some are looking better than others so far. I did seem to sense that blocking in the Barents-Kara Seas region might be more difficult relative to the past two winters, which so far is correct. Though the expectation of more Greenland blocking is so far, way off. I also mentioned in this blog and several subsequent blogs, if the PV remains strong then the overall pattern is likely to be mild across the Northern Hemisphere (NH), which has been correct.

The last point of ridging in the eastern North Pacific forcing cold air in either western or eastern North America depending on where the ridge axis sets up is looking pretty good. But based on the weather model forecast I do find it curious that the core of the cold is focused across Canada and in the Western US similar to the last two winters;

this despite that the PV has behaved very differently so far this winter compared to the last two winters. And to be honest not sure what to make of that.

Near Term Conditions

1-5 day

The AO is currently positive (**Figure 1**) with negative geopotential height anomalies across the Arctic and mixed geopotential height anomalies across the mid-latitudes of the NH (**Figure 2**). And with negative geopotential height anomalies across Greenland and Iceland (**Figure 2**), the NAO is positive as well.

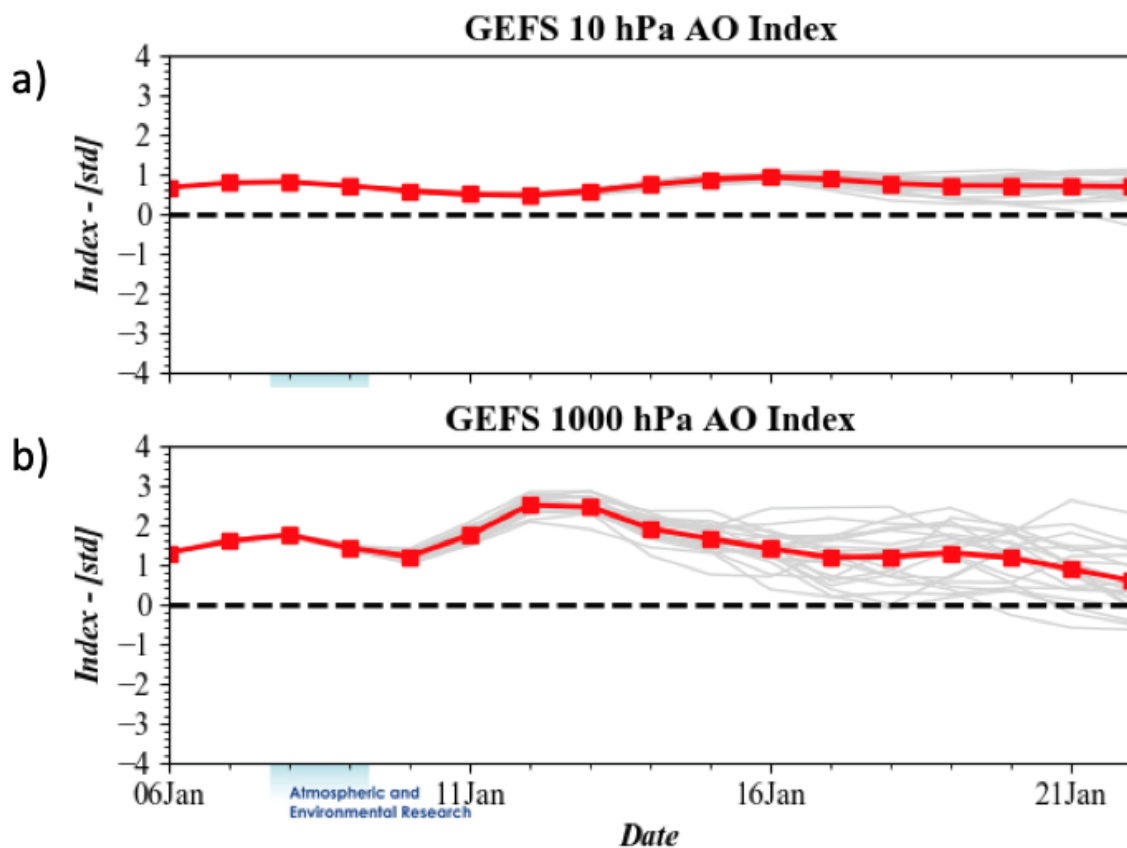


Figure 1. (a) The predicted daily-mean AO at 10 hPa from the 00Z 6 January 2020 GFS ensemble. (b) The predicted daily-mean near-surface AO from the 00Z 6 January 2020 GFS ensemble. Gray lines indicate the AO index from each individual ensemble member, with the ensemble-mean AO index given by the red line with squares.

This week ridging/positive geopotential height anomalies are predicted to dominate Europe with troughing/negative geopotential height anomalies mostly confined to the eastern Mediterranean (**Figure 2**). General high heights and lack of snow cover will

result in normal to above normal temperatures across much of Europe including the UK with the possible exception of normal to below normal temperatures across the Balkan States and Turkey due to northerly flow on the backside of the Mediterranean trough (**Figure 3**). This week, ridging/positive geopotential height anomalies are predicted to dominate much of Asia (**Figure 2**) favoring widespread normal to above normal temperatures across much of Asia (**Figure 3**). Exceptions are the northern India subcontinent, Central Asia and Eastern Siberia where regional troughing/negative geopotential height anomalies (**Figure 2**) are predicted to result in normal to below normal temperatures (**Figure 3**).

GEFS 1-5 Day Forecast 500 mb GPH/GPH Anomaly
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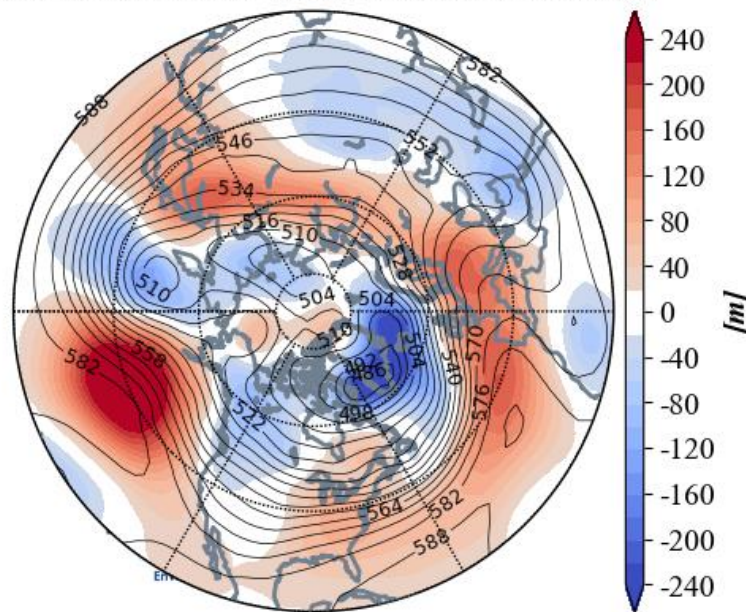


Figure 2. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 7 – 11 January 2020. The forecasts are from the 00z 6 January 2020 GFS ensemble.

This week, ridging/positive geopotential height anomalies anchored south of the Aleutians will force downstream troughing/negative geopotential height anomalies in western North America with more ridging/positive geopotential height anomalies in eastern North America (**Figure 2**). This is predicted to result in normal to below normal temperatures in Alaska, much of Canada and the Western US with normal to above normal temperatures across much of the Central and Eastern US (**Figure 3**).

GEFS 1-5 Day Forecast T2m Anomaly
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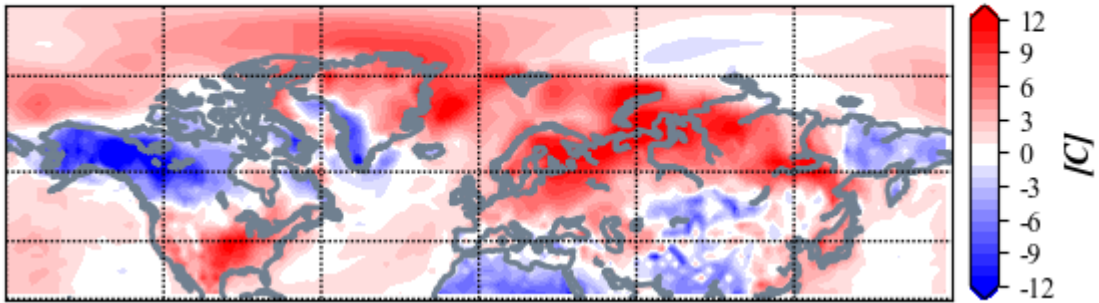


Figure 3. Forecasted surface temperature anomalies ($^{\circ}\text{C}$; shading) from 7 – 11 January 2020. The forecast is from the 00Z 6 January 2020 GFS ensemble.

Trouthing and/or cold temperatures are predicted to bring new snowfall across Western Russia, Siberia, the Tibetan Plateau, and Turkey (**Figure 4**). Trouthing and cold temperatures are predicted to bring new snowfall to much of Canada and the Northwestern US (**Figure 4**). Warmer temperatures are predicted to result in snowmelt for Northern and Eastern Europe, Alaska, the Northern Plains and New England (**Figure 4**).

GEFS 1-5 Day Forecast Mean 24-hour Snow Depth Change
INIT: 00Z 01/06/20 FCST: 01/07/20 to 01/11/20

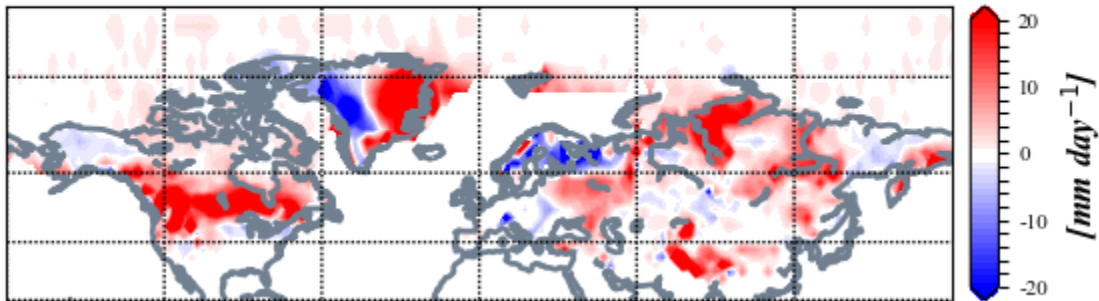


Figure 4. Forecasted snowdepth anomalies (mm/day ; shading) from 7 – 11 January 2020. The forecast is from the 00Z 6 January 2020 GFS ensemble.

Mid-Term

6-10 day

The AO is predicted to remain positive this period (**Figure 1**) as negative geopotential height anomalies persist across the Arctic with mixed geopotential height anomalies

across the mid-latitudes of the NH (**Figure 5**). And with negative geopotential height anomalies predicted across Greenland (**Figure 2**), the NAO is predicted to remain positive as well.

GEFS 6-10 Day Forecast 500 mb GPH/GPH Anomaly
INIT: 00Z 01/06/20 FCST: 01/12/20 to 01/16/20

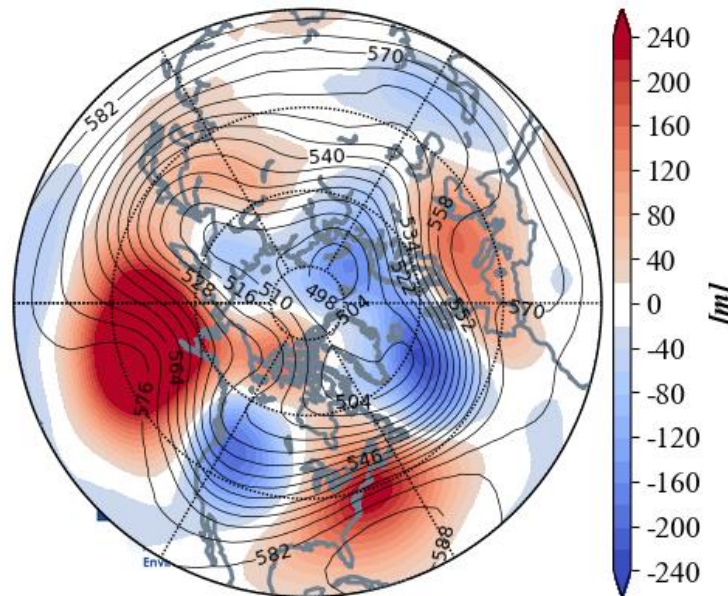


Figure 5. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 12 – 16 January 2020. The forecasts are from the 00z 6 January 2020 GFS ensemble.

The general pattern of ridging/positive geopotential height anomalies across much of Europe is predicted to continue this period (**Figures 5**). Once again generally high geopotential heights and lack of snow cover will favor widespread normal to above normal temperatures for much of Europe including the UK (**Figure 6**). Ridging/positive geopotential height anomalies will dominate Asia with exception of troughing/negative geopotential height anomalies across Southwestern Asia, the Urals and Eastern Siberia (**Figure 5**). This is predicted to yield normal to above normal temperatures for much of Asia with normal to below temperatures confined to parts of the Middle East, the north Indian subcontinent and Eastern Siberia (**Figure 6**).

GEFS 6-10 Day Forecast T2m Anomaly
INIT: 00Z 01/06/20 FCST: 01/12/20 to 01/16/20

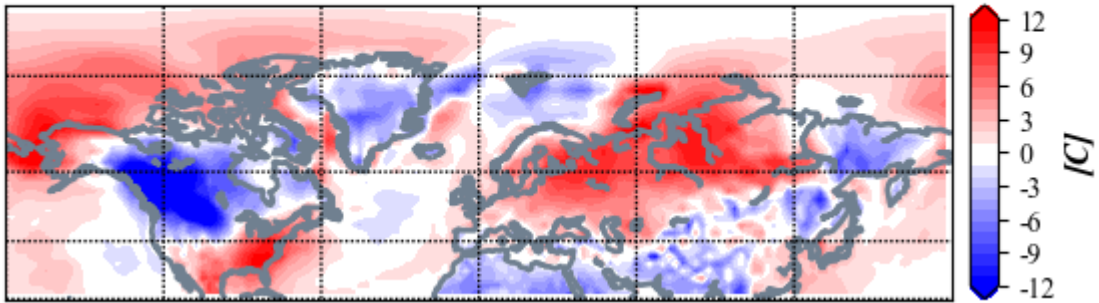


Figure 6. Forecasted surface temperature anomalies ($^{\circ}\text{C}$; shading) from 12 – 16 January 2020. The forecasts are from the 00Z 6 January 2020 GFS ensemble.

Once again ridging/positive geopotential height anomalies anchored south of the Aleutians will force downstream troughing/negative geopotential height anomalies in western North America with more ridging/positive geopotential height anomalies in eastern North America (**Figure 5**). This pattern is predicted to bring normal to below normal temperatures across Eastern Alaska, much of Canada and the Western US with normal to above normal temperatures in Western Alaska and the Eastern US (**Figure 6**).

GEFS 6-10 Day Forecast Mean 24-hour Snow Depth Change
INIT: 00Z 01/06/20 FCST: 01/12/20 to 01/16/20

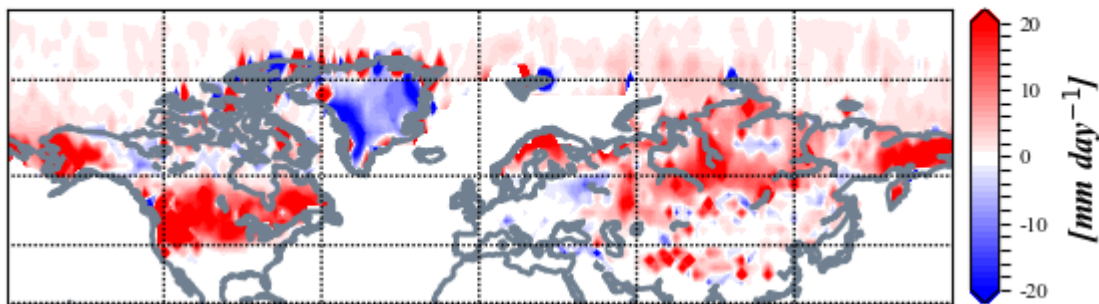


Figure 7. Forecasted snowdepth changes (mm/day ; shading) from 12 – 16 January 2020. The forecasts are from the 00Z 6 January 2020 GFS ensemble.

Troughing and/or cold temperatures will support the potential for new snowfall across much of Northern Asia, possibly Western Russia, Scandinavia, the Tibetan Plateau, much of Southern Canada and the Northwestern US (**Figure 7**). Some snowmelt is predicted in the Baltic States, the Alps and the Middle East (**Figure 7**).

11-15 day

With persistent negative geopotential height anomalies predicted for the Arctic (**Figure 8**), the AO is predicted to remain positive this period (**Figure 1**). With predicted negative pressure/geopotential height anomalies across Greenland (**Figure 8**), the NAO is likely to remain positive this period as well.

GEFS 11-15 Day Forecast 500 mb GPH/GPH Anomaly
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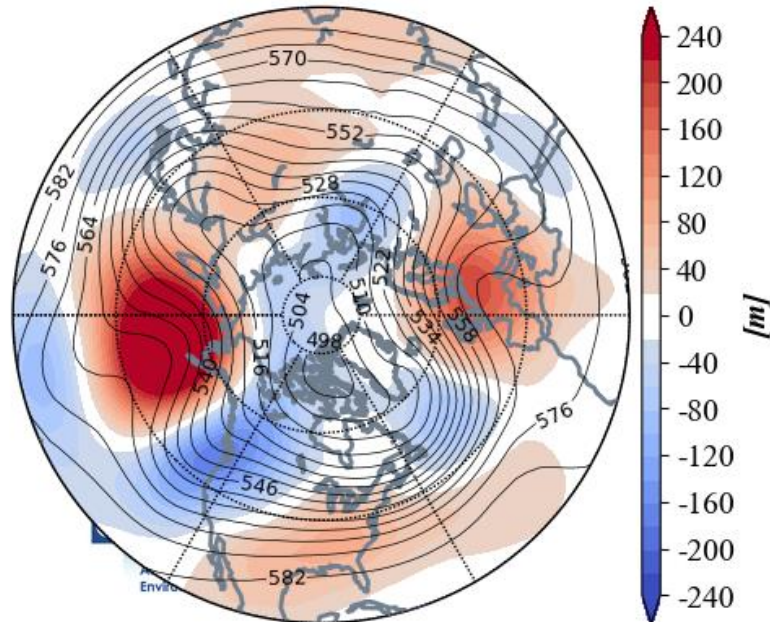


Figure 8. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 17 – 21 January 2020. The forecasts are from the 00z 6 January 2020 GFS ensemble.

Ridging/positive geopotential height anomalies will continue to dominate much of Europe (**Figures 8**). Above normal heights dominating the region will continue to favor widespread normal to above normal temperatures across much of Europe including the UK this period (**Figures 9**). Widespread ridging/positive geopotential height anomalies are predicted to persist across Asia with some regional troughing/negative geopotential height anomalies over the Urals and extending into Siberia (**Figure 8**). This pattern favors normal to above normal temperatures across much of Asia with normal to below normal temperatures mostly confined to parts of Central Asia and Siberia (**Figure 9**).

GEFS 11-15 Day Forecast T2m Anomaly
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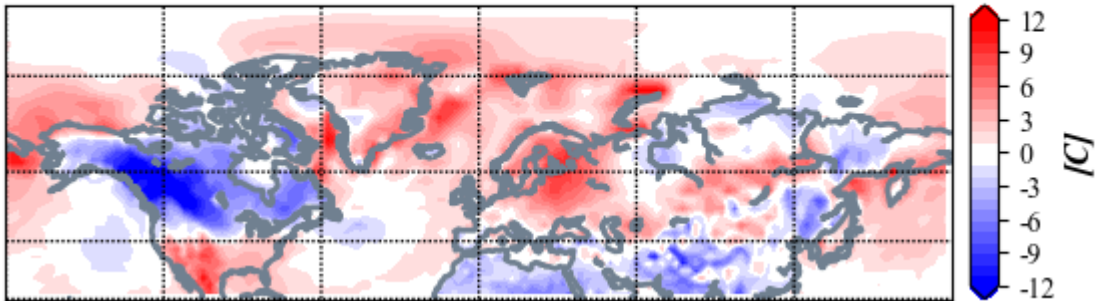


Figure 9. Forecasted surface temperature anomalies ($^{\circ}\text{C}$; shading) from 17 – 21 January 2020. The forecasts are from the 00z 6 January 2020 GFS ensemble.

Persistent strong ridging/positive geopotential height anomalies south of the Aleutians will continue to support downstream troughing/negative geopotential height anomalies across western North America with ridging/positive geopotential height anomalies in the Eastern US (**Figure 8**). This pattern is predicted to favor normal to below normal temperatures across Alaska, much of Canada and the US along the Canadian border, especially the Northwestern US with normal to above normal temperatures for much of the Southern and Eastern US (**Figure 9**).

GEFS 11-15 Day Forecast Mean 24-hour Snow Depth Change
INIT: 00Z 01/06/20 FCST: 01/17/20 to 01/21/20

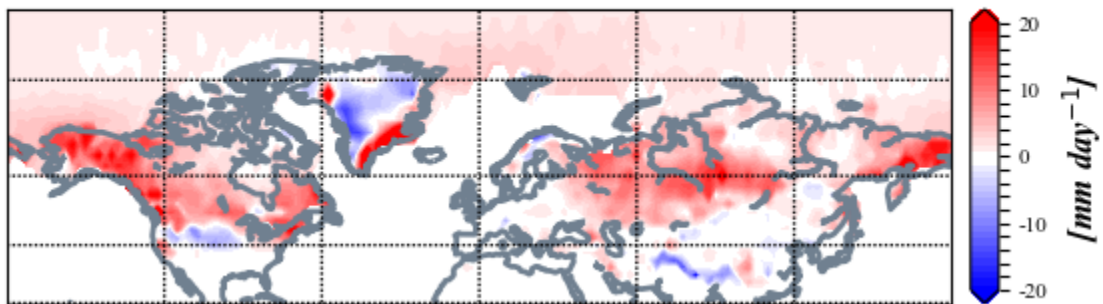


Figure 10. Forecasted snow depth changes (mm/day ; shading) from 17 – 21 January 2020. The forecasts are from the 00z 6 January 2020 GFS ensemble.

Troughing and/or cold temperatures will support new snowfall across much of northern Asia, Western Russia and possibly Eastern and Central Europe (**Figure 10**). New snowfall is possible across much of Alaska, Canada and the Northeastern US (**Figure 10**). Some snowmelt is possible in Central Asia and the US Plains (**Figure 10**).

Longer Term

30-day

The latest plot of the polar cap geopotential height anomalies (PCHs) currently shows normal to below normal PCHs in the troposphere and stratosphere (**Figure 11**). The cold PCHs in the lower troposphere since the end of December appear to be coupled with and in response to downward propagation of cold PCHs in the middle stratosphere due to a normal to strong PV since mid-December (**Figure 11**).

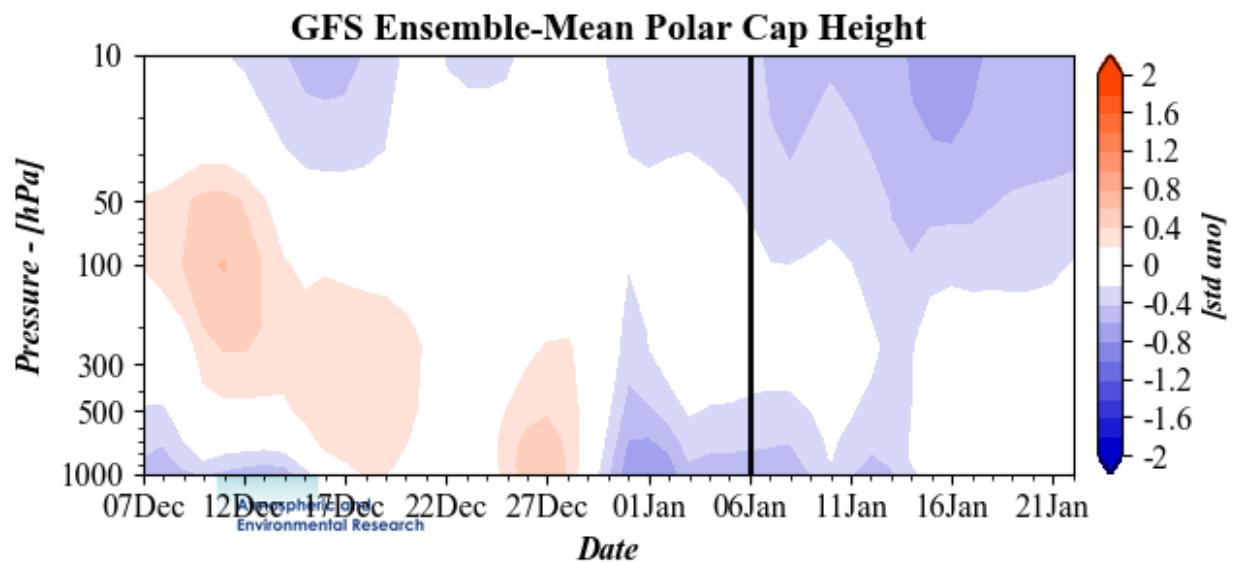


Figure 11. Observed and predicted daily polar cap height (i.e., area-averaged geopotential heights poleward of 60°N) standardized anomalies. The forecasts are from the 00Z 6 January 2020 GFS ensemble.

The plot of Wave Activity Flux (WAFz) or poleward heat transport shows a relatively quiet two-week period week with only one weak positive anomalies predicted for the end of this week (**Figure 12**). The predicted positive WAFz for the upcoming week are predicted to be followed by weak negative anomalies over the weekend and into early next week. The quiet WAFz is supportive of an ongoing normal to relatively strong PV.

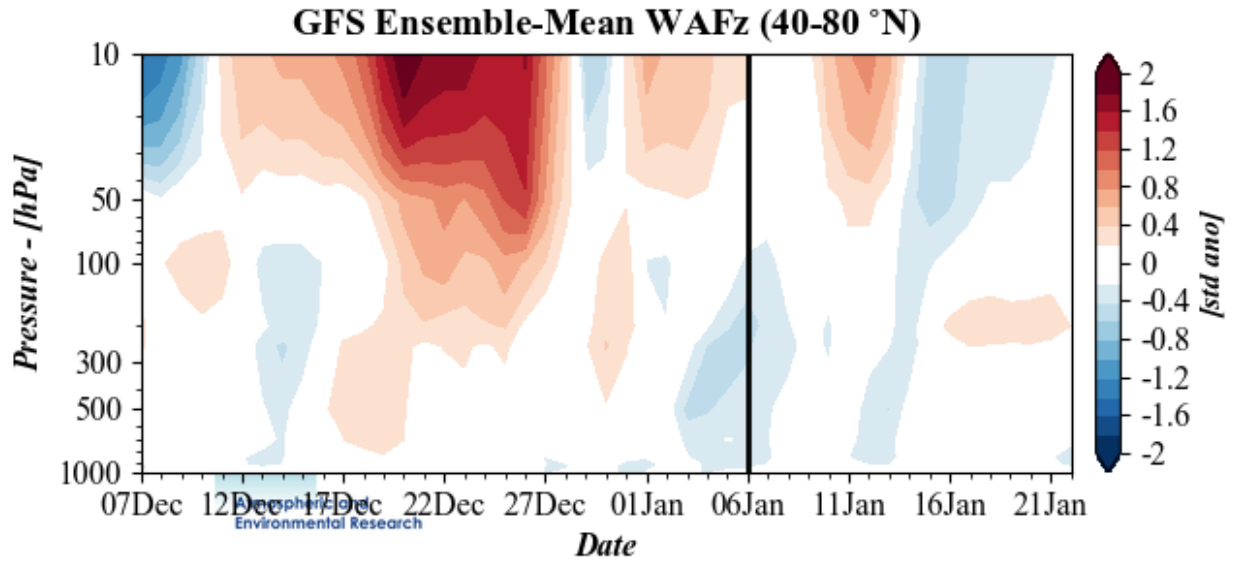


Figure 12. Observed and predicted daily vertical component of the wave activity W_{ux} (WAFz) standardized anomalies, averaged poleward of 40-80°N. The forecast is from the 00Z 6 January 2020 GFS ensemble.

The stratospheric AO is currently slightly positive (**Figure 1**) reflective of a relatively normal PV and the stratospheric AO is predicted to remain slightly positive the next two weeks (**Figure 1**). Little change is expected in the strength of the PV over the next two weeks.

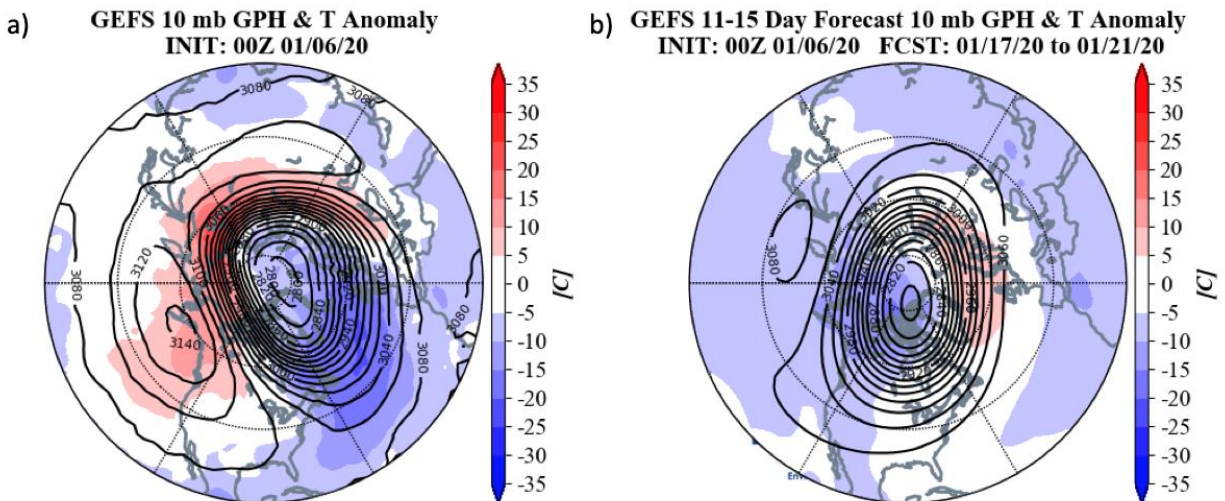


Figure 13. (a) Analyzed 10 mb geopotential heights (dam; contours) and temperature anomalies (°C; shading) across the Northern Hemisphere for 6 January 2020. (b) Same

as (a) except forecasted averaged from 17 – 21 January 2020. The forecasts are from the 00Z 6 January 2020 GFS operational model.

Currently the stratospheric PV remains centered near the Northeastern tip of Greenland (**Figure 13**). The largest negative temperature departures in the polar stratosphere are over Greenland extending eastwards into the Laptev Sea, likely supporting the predicted low tropospheric heights in that region (see **Figures 2, 5 and 8**).

The main warming and ridging in the polar stratosphere is centered across Northern Asia and into Alaska (**Figure 13**). Over time only weak WAFz pulses are predicted and therefore the polar stratospheric warming will circulate around the periphery of the Arctic and weaken over Northern Europe (**Figure 13**). With no direct advection of heat into the central Arctic the PV will remain centered near the North Pole (**Figure 13**). There are signs of the PV becoming a little more elongated along an axis from Siberia into Western Canada (**Figure 13**). This axis is at least suggestive of the coldest temperatures in the NH from Siberia and into Western Canada.

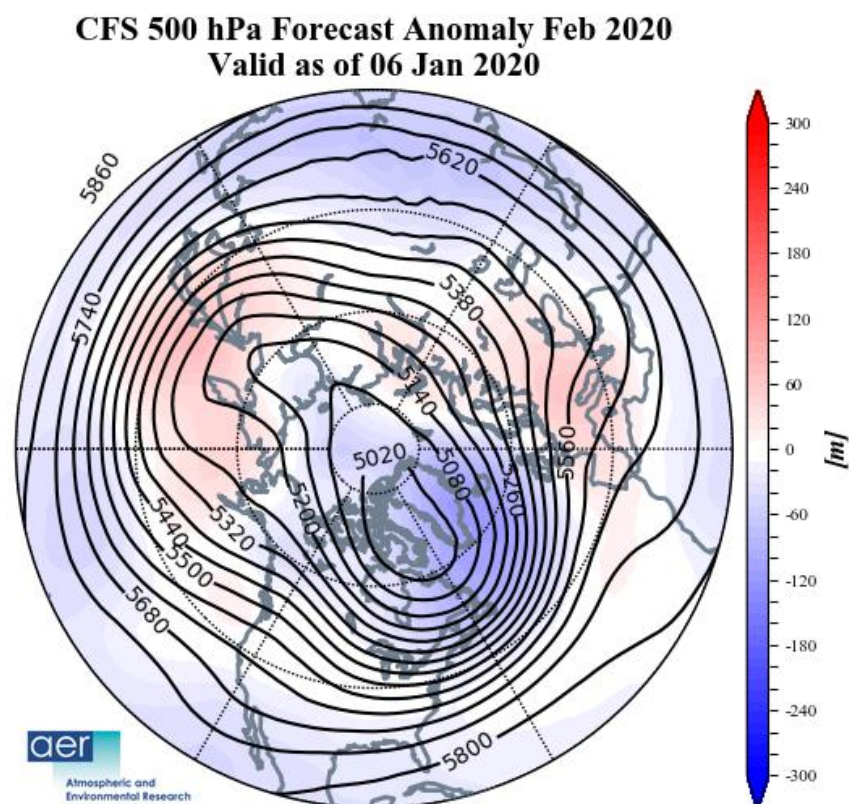


Figure 14. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere for February 2020. The forecasts are from the 00Z 6 January 2020 CFS.

I include in this week's blog the monthly 500 hPa geopotential heights (**Figure 14**) and the surface temperatures (**Figure 15**) forecast for February from the Climate Forecast System (CFS; the plots represent yesterday's four ensemble members). The forecast for the troposphere is ridging across Europe, the Dateline and western North America with troughing in Western and Eastern Asia and eastern North America (**Figure 14**). This pattern favors relatively mild temperatures for Europe, Western Asia, Western Canada and the Western US with seasonable to relatively cold temperatures for much of Central and Eastern Asia, Alaska, Eastern Canada and the Eastern US (**Figure 15**). I have particularly low confidence in the forecast.

CFS T2m Forecast Anomaly Feb 2020 Valid as of 06 Jan 2020

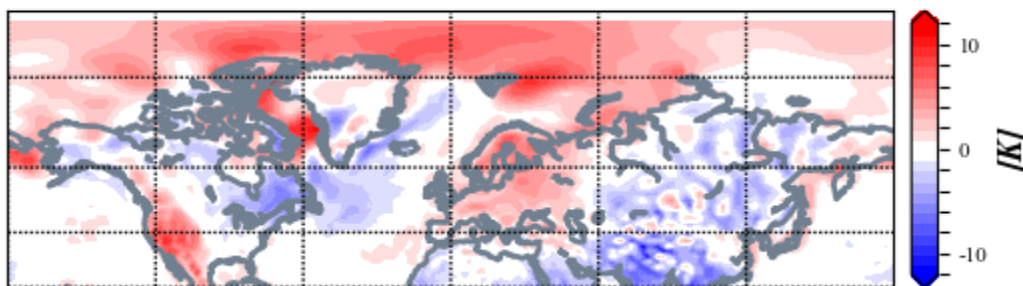


Figure 15. Forecasted average surface temperature anomalies ($^{\circ}\text{C}$; shading) across the Northern Hemisphere for February 2020. The forecasts are from the 00Z 6 January 2020 CFS.

Surface Boundary Conditions

Arctic sea ice extent

Arctic sea ice growth rate continues to grow slowly and remains well below normal; though the weather pattern remains favorable for further sea ice growth. Negative sea ice anomalies exist in three regions: the Bering Sea, around Greenland-Canadian Archipelagos and Barents-Kara Seas. The anomalies in the North Pacific sector have shrunk (**Figure 16**) and based on model forecasts negative sea ice anomalies in the Bering Sea can shrink further in the next two weeks. Below normal sea ice in and around Greenland and the Canadian Archipelagos may favor a negative winter NAO, though there are no signs of such a scenario. Based on recent research low sea ice anomalies in the Chukchi and Bering seas favors cold temperatures in central and eastern North America while low sea ice in the Barents-Kara seas favor cold temperatures in Central and East Asia, however this topic remains controversial. Recent research has shown that regional anomalies that are most highly correlated with the strength of the stratospheric PV are across the Barents-Kara seas region where low Arctic sea ice favors a weaker winter PV.

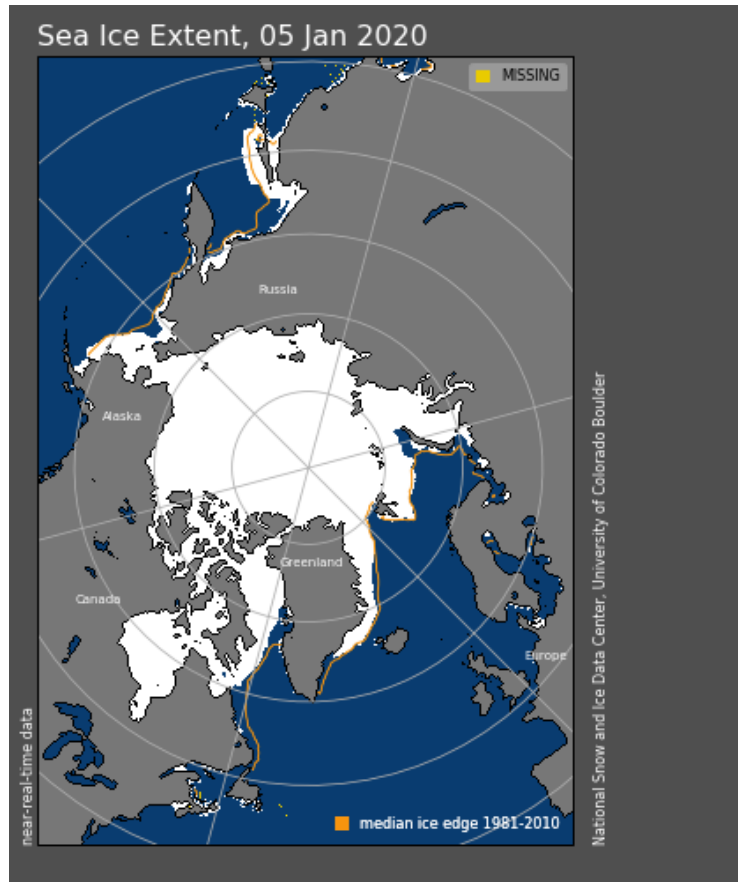


Figure 16. a) Observed Arctic sea ice extent on 5 January 2020 (white). Orange line shows climatological extent of sea ice based on the years 1981-2010.

SSTs/El Niño/Southern Oscillation

Equatorial Pacific sea surface temperatures (SSTs) anomalies have cooled and neutral El Niño/Southern Oscillation (ENSO) conditions seem most likely (**Figure 17**). Observed SSTs across the NH remain well above normal especially near Alaska and in the Gulf of Alaska though below normal SSTs exist regionally especially west of South America. Warm SSTs in the Gulf of Alaska may favor mid-tropospheric ridging in the region this winter.

SST Anomaly - Week Ending 05 Jan 2020

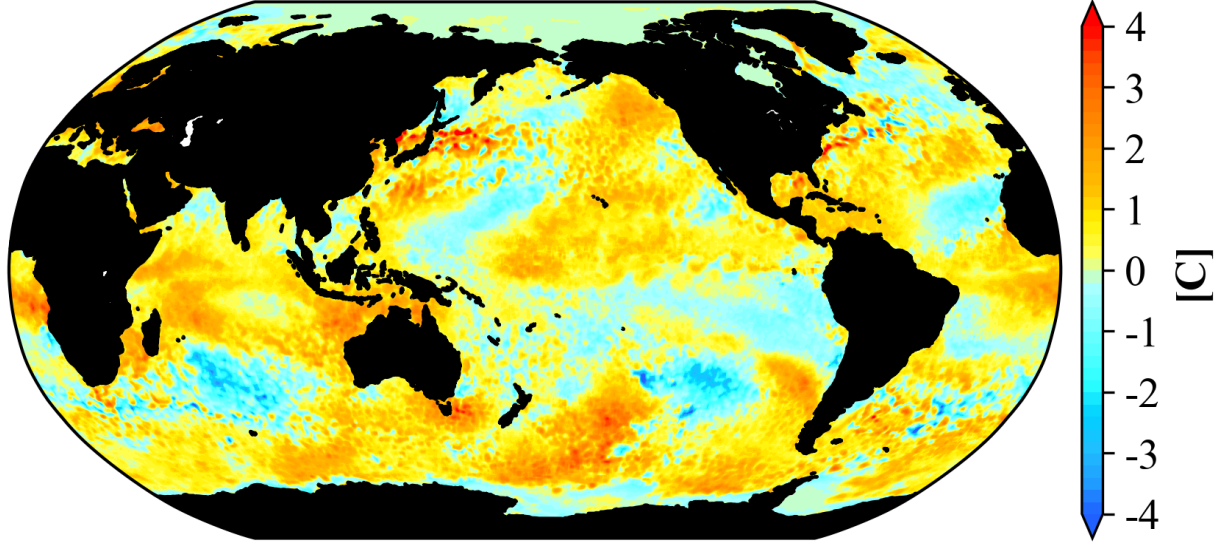


Figure 17. The latest weekly-mean global SST anomalies (ending 5 January 2020). Data from NOAA OI High-Resolution dataset.

Currently no phase of the Madden Julian Oscillation (MJO) is favored (**Figure 18**). The forecasts are for the MJO to emerge into phases four this week and five next week. MJO phases four and five favors ridging south of the Aleutians, troughing in western North America with more ridging in the Eastern US. Based on the weather model forecasts, MJO is likely to have a strong influence on North American weather the next two weeks.

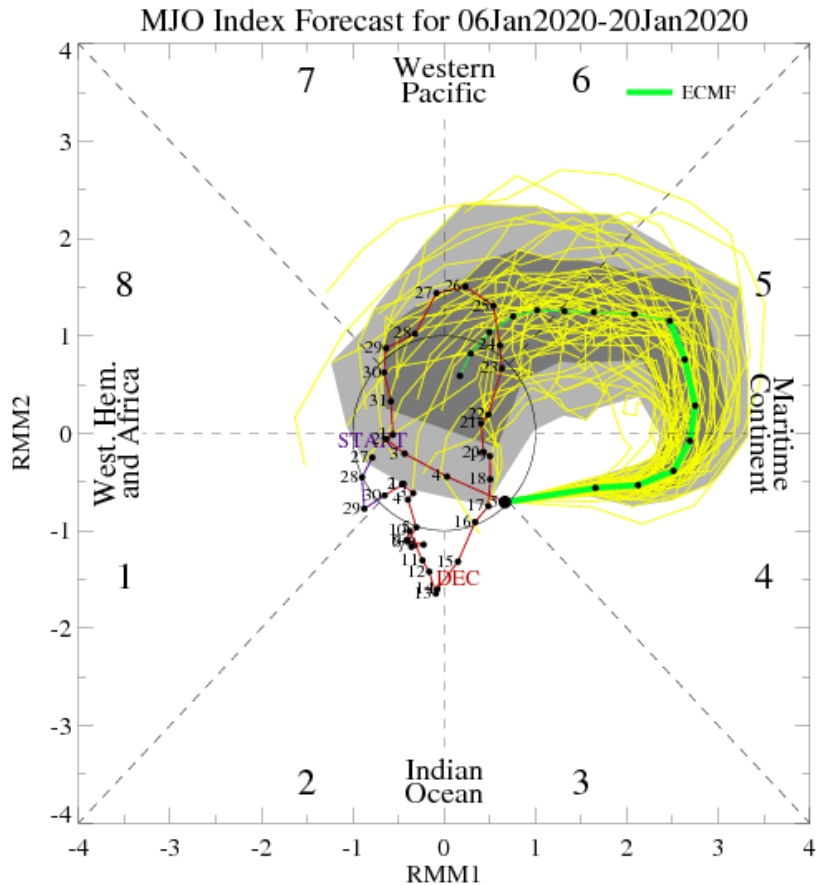


Figure 18. Past and forecast values of the MJO index. Forecast values from the 00Z 6 January 2020 ECMWF model. Yellow lines indicate individual ensemble-member forecasts, with the green line showing the ensemble-mean. A measure of the model “spread” is denoted by the gray shading. Sector numbers indicate the phase of the MJO, with geographical labels indicating where anomalous convection occurs during that phase. Image

source: <http://www.atmos.albany.edu/facstaff/roundy/waves/phasediags.html>

Northern Hemisphere Snow Cover

Snow cover has remained steady across Eurasia and remains near decadal lows. I don't see any major advance in the near future. Above normal snow cover extent in October, favors a strengthened Siberian high, cold temperatures across northern Eurasia and a weakened polar vortex/negative AO this upcoming winter followed by cold temperatures across the continents of the NH.

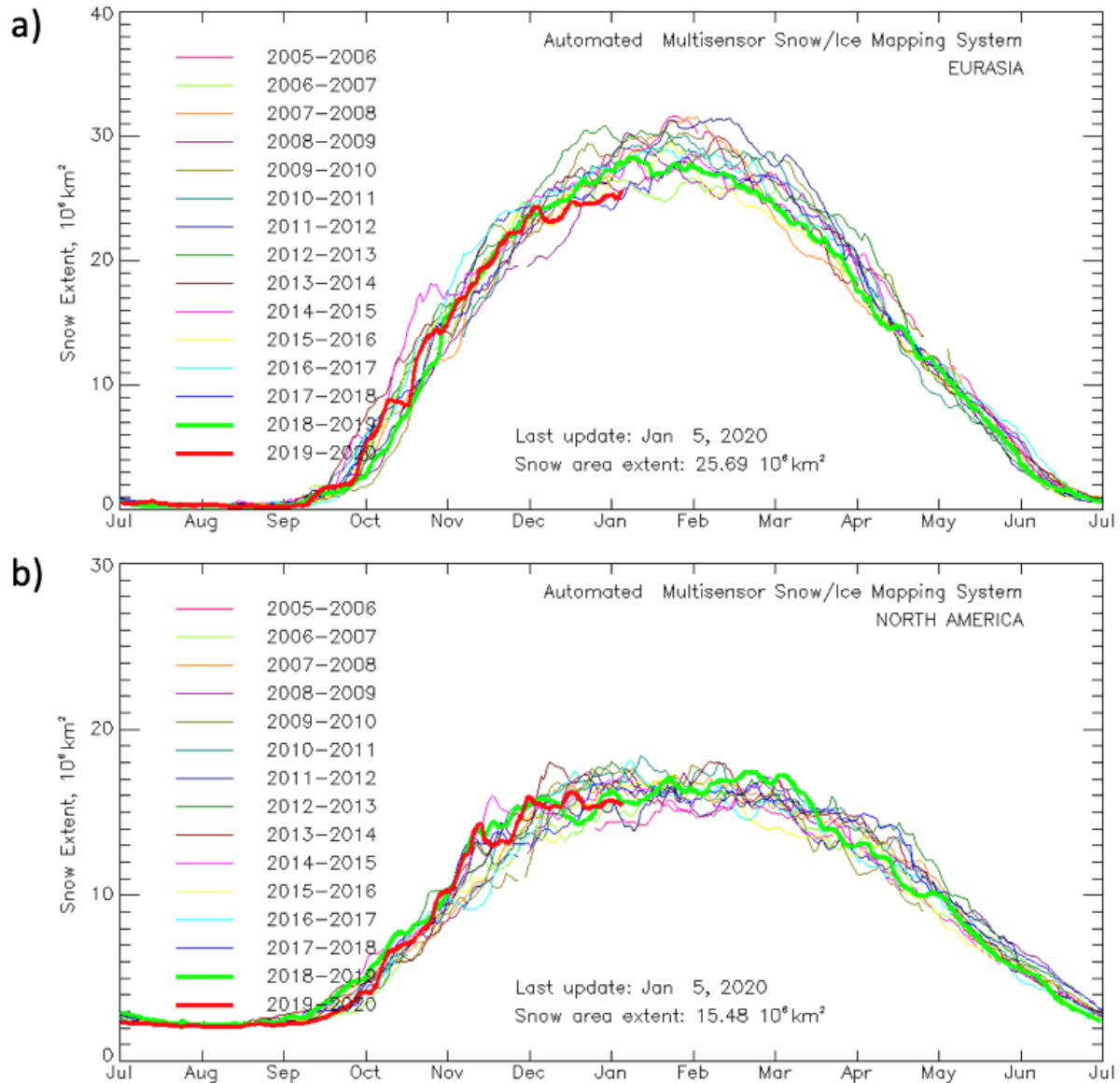


Figure 19. Observed Eurasian (top) and North American (bottom) snow cover extent through 5 January 2020. Image source: https://www.star.nesdis.noaa.gov/smcd/emb/snow/HTML/snow_extent_plots.html

North American snow cover remains steady near decadal lows. The predicted negative phase of the Pacific/North American pattern is favorable for the advance of snow cover across the US. The early advance of snow cover across Canada this fall, has likely contributed to the expanse of cold temperatures across Canada.